TITLE: New Auditory Damage Risk Criteria and Standard for Impulse Noise

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Abstract This paper discusses the Auditory Risk Criteria as currently being proposed in a draft ANSI Standard. The criteria include two general prediction methods for estimating the hazard. One method, called the survey method, uses the A-weighted energy under a hearing protector to estimate the amount of hearing loss likely to be found for an exposed population. The second method, called a computer modeling method, provides an assessment for each individual waveform of an exposed population. The standard will provide the necessary software for this model. The standard will not provide specific criteria while wearing hearing protection, but instead will provide suggested validation procedures to insure that a specific program in which hearing protection is used actually is preventing hearing loss, either temporary or permanent. Criteria for identifying acoustic trauma and excessive fetal impulse noise will also be included.

A. What is wrong with our current standards and damage risk criteria?

There are several problems with most of the current procedures for the evaluation of impulsive noise. Perhaps the most significant problem is the assumption that the average wearer will properly use hearing protection. Experience has clearly shown that this is a very poor assumption for non-expanding plugs, a poor assumption for expanding plugs, and a fair assumption for muffs Over the last 15 years, it has finally been realized that for non-impulse noise, the laboratory rating for hearing protector performance was far greater than what could be obtained in the field. For this reason, the U.S. National Institute for Occupational Safety and Health (NIOSH) has recently suggested de-rating hearing protector performance. They suggested that muffs should use 75% of their rated attenuation, formable plugs 50% and all other plugs should use only 30% of their rated performance. (NIOSH, 1998). JAYCOR has recently written a report (Chan, et. al., 1999) that suggest the US MIL Standard could be raised by 9 dB as based on human studies using muffs or expandable plugs. If one were to apply these numbers to the problem of high level impulses, we might indeed give a effective reduction of 38 dB for the muffs, thus raising the mil standard by 9 dB. By the same token, we would give the expandable plug only 26 dB, thus lowering the mil standard by 3 dB. For the non-expandable plug, only 13 dB of attenuation would be given, effectively lowering the mil standard by 16 dB. Are such reductions warranted for impulse noise? I don't know. We did use the EAR expandable plug in the Albuquerque studies on occasion. We never observed an auditory failure with this plug. However we (EGG) always checked the performance of that EAR plug before a subject was exposed. (Johnson, 1994) This will not be the case when these plugs are used in the field. Soldiers will not always get the proper attenuation of these plugs. Muffs, on the other hand, are hard not to fit right. The Albuquerque studies have shown that leaks around the seals of the muffs should not be very critical. In fact, the blasts themselves caused the muffs to move, which again emphasizes that training when using the muff type protector is not so critical. In the studies at Albuquerque, there was never an auditory failure while using an intact RACAL muff at the non-auditory limits. Thus, the non-auditory limits certainly must set the upper exposure values for auditory risk when using double protection. With a little more caution, the non-auditory limit probably sets the auditory risk limit when using muffs alone. For other hearing protection devices, there will not be any damage risk curves suggested. Instead, there will be a procedure recommended that will qualify a protection program that uses a specific type of protector for a specific type of exposure. The protection program will include a specific type of hearing protection, the training to be used, the management of the program, and the proof that the program works on a day to day basis.

Another problem with the current standards is that they take into consideration the duration of the impulse. At first glance, this has always seemed to be a reasonable approach. The assumption has been that an impulse with a longer duration must be more of a hazard. Even though different damage risk criteria calculated the duration somewhat differently, e.g. the "B-duration", and the 'D-duration", longer duration exposures were always considered more hazardous. Chan, et al concluded that the longer duration impulses were less hazardous. I'm beginning to think they are right.

So what are my suggestions? As the chair of the ANSI working group S-3 62, "The Effects of Impulse Noise", I have hopes that our working group can produce a standard that could serve as a replacement for the mil standard. A working draft has been prepared, however it is not without its faults. One of the features of the draft standard is the incorporation of the damage risk computer model developed at Aberdeen. (Price and Kalb, 1996). At a minimum, I would like to use the model in order to predict the mechanical performance of different hearing protection devices. Obviously, it could be the entire mil standard. However, there is not a consensus of the working group to support that position. In any case, the Aberdeen model will have

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difficulty with the question of the subject fit or soldier's field fit. The current draft standard will also specify the amount of auditory testing needed, including testing in the field. The standard may also have a section on acoustic trauma. In summary, the standard may be more of a set of standardized procedures than a set of hard numbers.

B. Elements of the new standard

This proposed ANSI Standard will present two general methods for the evaluation of the expected "noise-induced permanent threshold shift" (NIPTS) from impulse noise or a combination of impulsive and non-impulsive noise. The two methods consist of a survey method and an auditory modeling method. The survey method will consist of measuring or estimating the A-weighted sound exposure under hearing protection devices. With a small correction factor that relates the gain provided by the human anatomy, the tables of ANSI S3.44 or ISO R-1999, which relate noise exposure to NIPTS, may be used. For exposures in which the peak level is above 140 dB, the auditory modeling method must be used when the ears are unprotected The survey method may be used if the sound that reaches the ear under a hearing protector exceeds a peak of 140 dB if the provided the sound originates outside the hearing protector. The benefit of the survey method is that it provides an estimate of the hazard of the total noise exposure of a person, including both continuous and impulsive noise.

The auditory modeling method consists of measuring the waveform of the impulse either outside or under the hearing protector to be used. The output of the model is a prediction of Auditory Damage Units (ADUs). . The second method is considered more precise because scientific evidence indicates that the basic mechanisms that produce loss in the ear change as the level rises and follow fundamentally different laws. At lower levels where energy measures are appropriate, losses accumulate relatively slowly, over a period years with daily exposure. On the other hand, at higher levels where the loss mechanisms are fundamentally mechanical, the ear may be extensively and irreversibly damaged in a few milliseconds. This change in the ear's response suggests different methods of analysis. Unfortunately, the transition from one loss mode to the other is a complex function of frequency, level, state of middle ear muscles, specific timing of elements in a waveform and so forth. Because of the possibility of instantaneous loss with no warning signs, any time that pressure can be predicted to rise above 140 dB; hearing protection should be worn.

As a result of the uncertainties associated with high level exposures, the auditory modeling method provides a prediction of hazard for the 95%ile ear (most susceptible). The survey method includes the possibility of calculating hearing loss for any percentile of the population with the algorithms in ISO-1999. For consistency in the application of this standard, however, it is recommended that calculation for the 95%ile ear should be used.

To use the auditory modeling method, you run a computer program that will be provided as part of this standard. This program is based on a mathematical model of the human ear designed to predict hazard from intense sounds. It requires that the full-digitized waveform be on a file accessible by the program, typically on a disc. The standard includes the algorithms necessary for importing waveforms for processing by the standard. In addition to analyzing waveforms measured in the free field, this method analyzes waveforms that have been measured at the ear canal entrance or at the eardrum position. Thus, it is possible to evaluate hearing hazard under hearing protectors. Details of the requirements and procedures will appear in an Appendix.

The use of two methods for rating hazard that are based on different premises is an unavoidable consequence of the complexity of the ear's response at high sound pressure levels as well as the accompanying uncertainties in real exposures. If there is a question as to which of the two methods should be applied, the standard will suggest both methods should be used and the greater hazard value accepted unless counter-indicated by audiometry.

The standard also provides a general procedure for qualifying a specific hearing protector for a specific type of waveform. These procedures attempt to take into account the variability in actual protection due the wearer's training the use of the protector, individual susceptibility to the particular impulses, fitting problems of the protector, variability of the impulses, and any other factors that effect the hazard of the exposure.

The standard will also define when acoustic trauma occurs. Possible courses of action will be suggested in an appendix.

The standard will also recommend that a hearing conservation program be implemented whenever individuals are knowingly exposure to levels above 140dB.

Finally, the standard will also suggest that pregnant persons should not be exposed to peak levels above a c-weighted peak of 155 after the fifth month of pregnancy. This recommendation is to protect the hearing of the fetus. The measurements should be at the abdominal wall.

The standard recommends that the evaluation of the non-auditory risk of injury be made whenever the peak level exceeds 180 dB.

C. Specific Details of the Proposed Standard

1. The survey method using A-weighted Sound Exposure:

a General To estimate hearing impairment and risk of hearing handicap as a result of exposure to noise, the average A-weighted sound exposure, $E_{A,8h}$ and/or the noise exposure level normalized to a nominal 8 h working day, L_{A8hn}, (shall be either 1) measured directly by sound exposure meters or integrating sound level meters, or 2) calculated from sound pressure measurements and exposure time and hearing protection attenuation values. Such measurements may be made with instruments that are either stationary or attached to the noise-exposed person.

The measurement locations and the duration of the measurements shall be chosen so as to represent the exposure to noise experienced during a typical day by the population at risk.

b Instrumentation For direct measurement of equivalent continuous A-weighted sound pressure levels, integrating-averaging sound level meters shall comply with IEC 804, type 2 or better.

c Calibrating and checking. All equipment shall be calibrated, and the configuration for calibrating and checking shall be in accordance with the manufacturer's instructions.

> The user shall make a field check at least before and after each series of measurements. An electric check of amplifiers, recorders and indicators shall be made as well as an acoustic check of the sensitivity of the microphone and/or the total system. This is especially important when the microphone is placed into the ear canal.

d Microphone positions When the measurement of sound pressure to determine the A-weighted sound exposure and/or the equivalent continuous A-weighted sound pressure level for the unprotected ear, the measurements should be made with the microphone located at the position(s) normally occupied by the head of the person concerned, the person being absent. For measurements made under muff type hearing protectors, the microphone should be located at the entrance of the external ear canal of the ear receiving the higher value of the A-weighted sound exposure or the equivalent continuous A-weighted sound pressure level. All measurements shall be corrected by the pinna/ear-canal-gain function.

For measurements made under insert type hearing protectors, the microphone should be located such that it measures in the cavity between the insert device and the tympanic membrane of the ear receiving the higher value of the A-weighted sound exposure or the equivalent continuous A-weighted sound pressure level. All measurements shall be corrected by the pinna/ear-canal-gain function.

The exact positions at which the measurements are made shall be reported.

e Measurement: Pertinent details of the measuring instrumentation, measurement procedure and conditions prevailing during the measurements shall be carefully recorded and kept for reference purposes. When reporting the measurement result, an estimation of the overall measurement uncertainty shall be stated taking into account the influence of factors such as: measuring instrumentation, microphone positions, number of measurements, time and spatial variation of the noise source.

f Daily exposure to noise over an extended time period. The daily A-weighted sound exposure or the noise exposure level shall be determined for a sufficient number of days and for the individuals under consideration to allow the determination of the average exposure to noise for the years or decades under consideration. If measured directly, the determination of the daily exposure shall be made by instrumentation that provides an indication of the A-weighted sound exposure or the equivalent continuous A-weighted sound pressure level. Such instrumentation integrates the fluctuations of the noise produced by a time-varying noise source or by movement of the person from place to place. The fluctuations may be spread over a wide range of levels and/or be of irregular time characteristic. The fluctuations may also include noises of impulsive character. If the daily exposure to noise is estimated by some method, such as task-based analysis, then the all of a person's noise exposing activities must be considered. As a practical manner, the daily noise exposure may be calculated from a combination of actual measurements and estimates. The daily noise exposures should be combined to provide the average daily exposure to noise over the total number of days for an individual or a group of individuals. When the noise is not the same from day to day, as certainly may occur for impulse noise from training, the equivalent continuous A-weighted sound pressure level averaged over a longer period (not exceeding 1 year) should be adjusted upward so the daily equivalent continuous A-weighted sound pressure level on the worst day is not more than 10 dB higher.

> NOTE - For exposure to noise too irregular for this Standard to be applied without the above adjustment, monitoring audiometry is strongly recommended. Monitoring audiometry, in conjunction with audiometric data base analysis, is good practice anytime.

g Use of Pinna/ear-canal gain: Because all of the formula in section 6 of this standard use a noise exposure calculated at the position of the center of the worker's head if the worker was present, the gain of pinna and ear canal needs to be subtracted from the measured or calculated value measured under the insert type hearing protector. The gain ranges from 6 to 14 decibels (Shotland, 1996 and Shotland, et. al., 1994). However, for the purposes of this standard, the gain of 6 dB will be used. Thus 6 decibels will be subtracted from all exposure levels measured or predicted under insert hearing protection.

This correction will not be recommended for muff type protectors.

h Estimation of noise-induced permanent threshold shift, N

1)) The expected Noise-induced permanent threshold shift can be calculated from the procedures in ISO R 1999 or in ANSI S3.44.
2)) Use of NIPTS Values The NIPTS values can be used to calculate the expected hearing impairment in a Population by using the procedures outlined in either ISO R1999 or ANSI S3.44

2. The auditory modeling method (ADM) using the computer model developed at Aberdeen

a. General
The model is based around a theoretically based mathematical model of the human ear designed to predict auditory hazard for sounds with peak pressures high enough that the damage mechanism within the inner ear is fundamentally mechanical (Kalb and Price, 1987, Price and Kalb, 1996; 1991). The model is not only theoretically based; but is structured so that its elements are conformal with the physical structure of the ear. This approach in a standard is not common; however it brings with it many advantages, among them the ability to generalize from specific experimental tests to new situations with a reasonable expectation that the analysis fits. It also allows the analysis to begin at various locations, such as the free field, ear canal entrance, or eardrum position, which means that any waveform measured at such a location can be analyzed. This is important because it makes it possible to evaluate the effect of hearing protectors without having to make assumptions about their attenuating properties. Single number estimates of effect used in the past (CHABA, 1968; MIL STD-1474X, 198?) obviously represent a great loss of information about a protector's effect. Such compromises are no longer necessary.
The presence of various non-linearity's in the ear's response at very high sound pressure levels has made the use of such a model not only desirable but also necessary. For instance, A-weighting can compensate for non-linearities with respect to frequency and as a result is commonly used in noise ratings. However, at very high sound pressure levels where Method II must be applied, the non-linearities associated with middle ear muscle activity and with a physical limit to stapes displacement cannot be adequately accounted for by essentially linear analyses such as filtering[1]. Hence, the necessity for a modeling approach.

b Measurement Requirements Specific to the Model To use existing methods of hazard analysis, some form of summary analysis of the waveform was needed e.g. a peak pressure, some measure of duration (A-duration, B-duration, C-duration, D-duration) or an A-weighted energy. Then a value could be read from a chart that would indicate the risk. The ADM, however, calculates displacements in the ear as a function of time and acoustic pressure. It therefore requires only a digitized waveform of the sound being analyzed as its input. The ADM includes basic algorithms for preparing waveforms for use with the method. Because the ADM allows predictions which include middle ear muscle effects (if desired), there is also a requirement that the waveform be stored in a manner that allows such calculations to be made. Algorithms that allow this will be included with the standard.
c. Format and Waveform Quality The waveform must be stored in ASCI format. Data may include time points as well as pressures or even multiple pressure histories in a file. The input-processing algorithm with the standard can handle the most common possibilities. The ADM represents an immense increase in use of information in the waveform. As a result, an accurate analysis requires a faithfully reproduced waveform. Good vertical resolution requires the use of at least a 12-bit digitizer (16 bit preferable) and good resolution in time requires a sampling rate of 40-50 kHz. If the waveform includes significant amounts of low frequency energy (even near 1 or 2 Hz, as do airbag waveforms) the recording system should reproduce it faithfully. It may be true that the ear doesn't hear such sounds; but low frequency sounds cause the middle ear to become non-linear and modulate the flow of energy into the cochlea. Put in traditional terms, the dynamic range of the recording should be at least 60 dB and the frequency response of the system should be essentially flat from 1 Hz to 20 kHz. The algorithms in the ADM require that the numbers in the waveform being processed be pressures in Pascals. Algorithms included with the standard allow any values to be adjusted so that the calculation will be accurate.
d. Applications of the ADM There are several application of the ADM that are suggested. These are as follows:
1)) The ADM can be used to predict the likelihood of hearing damage from exposures that occur when hearing protection is not worn. When used in this mode, the level that is equivalent to a daily eight-hour exposure to 85 dBA for a year is 250 Auditory Damage Units (ADUs).
2)) The ADM can be used to evaluate the relative auditory hazards of different weapon systems of the same general type.
3)) The ADM can be used to evaluate, for different hearing protectors used correctly, the relative effectiveness against the impulses of a specific type of weapon system.
Note: Because the ADM cannot predict how a hearing protector is going to be worn in practice, it cannot be used to validate the actual performance of a hearing protector.

3 The validation and documentation of hearing protection performance

a. General Because the actual protection against auditory damage of any hearing protective device depends so much how each individual user correctly wears the hearing protector device, the following validation procedures are recommended as standard practice. Because certain types of hearing protectors are more likely to be properly worn than others, the amount of validation will differ for different types of devices. Over the last 15 years, it has finally been realized that for non-impulse noise, the laboratory rating for hearing protector performance was far greater than what could be obtained in the field. For this reason, NIOSH has recently suggested de-rating hearing protector performance. They suggested that muffs should use 75% of their rated attenuation, formable plugs 50% and all other plugs should use only 30% of their rated performance. (NIOSH, 1997). Yet the use of a muff type plug alone was shown to safely protect the auditory system up to the non-auditory limit for exposures of 6 and 100 impulses. (Johnson, 1997). Thus the extent of the validation procedures needed is a function of the type of hearing protection used. In all cases a hearing conservation program should be in place.

b. Testing for excessive threshold shifts in hearing levels. For the recommended test populations indicated in paragraph c of this section, a hearing protector shall be consider validated for use for a specific type of waveform and peak level if the amount of TTS 1 to 5 minutes after the last exposure is less than that shown in table 3

TTS (1-5 min)

No of Users tested (N)	15. <TTS<25	25<TTS<Trauma	Trauma
20	1	0	0
40	2	1	0
80	4	2	1
>80	<.0	<.025*N	<.00125*N

c. The recommended minimum number of users tested for excessive temporary changes in their auditory thresholds follow:

1) Double protection using a muff and an formable plug:

a)) Starting level: Non-auditory limit for all types of impulses
b)) Initial validation None
c)) Yearly validation None

2) Double protection using a muff and a non- formable plug:

a)) Starting level: Non-auditory limit for all types of impulses
b)) Initial validation First 20 users
c)) Yearly validation None

3) Single protection using a muff:

a)) Starting level: Non-auditory limit for non- reverberant impulses; 185 dB peak for reverberant impulses
b)) Initial validation First 40 users,
c)) Yearly validation 20 users

4) Single protection using an expandable plug:

a)) Starting level: Non-auditory limit for non-`reverberant impulses; 185 dB peak for reverberant impulses
b)) Initial validation First 40 users
c)) Yearly validation 40 users

5) Single protection using a non-expandable plug:

a)) Starting level: 185 dB peak for non-reverberant impulses; 180 dB peak for reverberant impulses
b)) Initial validation First 80 users and 10% of all users
c)) Yearly validation The larger of 80 users or 10% of all users

d. Re-verification The purpose of the verification process is to insure that the hearing protection provides sufficient protection in at least 95 % of the users. If the verification fails, then one or more of the following actions should be undertaken before re-verification:

a)) Change hearing protection
b)) Improve training in use of the protectors
c)) Lower exposure levels
d)) Improve motivation on the use of protection.

4. Definition and Recommended actions for acoustic Trauma

a). Acoustical Trauma is considered to occur when the Temporary shift of hearing 2 minutes after exposure at any frequency is greater than 40 decibels. If the audiometric test is accomplished at a time longer than 2 min., the equation below should be used to determine if the TTS is sufficient to be considered acoustic trauma.

Time post exposure of audiogram at the freq. in question	TTS level at which Acoustic Trauma is assumed
<2min	40 dB
2 min to 928 min	15xlog(928/t) dB
>928 min	15 dB

Use of the above equation is for guidance only and assumes that the hearing thresholds of the victim were known previous to the incident. If the prior thresholds are not known, then the standard will suggest that the determination of acoustic trauma must be made entirely on the recommendation of the medical examiner.

b) Treatment The standard will recommend that treatment of acoustic trauma be undertaken. At the minimum, a rest period away from any noises above 75 decibels should be considered. Other treatments may be listed in an appendix. Because these treatments are not universally accepted, these treatments will be given for information only and will not be part of the standard.

5. Recommended elements of a hearing conservation Program

a). Introduction. Regardless of which method is used to predict the effects of Impulsive noise on hearing, the actual effect can be verified by giving routine audiograms to all exposed personnel. It recommended that semi-annual audiograms be given to all personnel routinely exposed to impulse noise with peak levels above 140 dB. In addition, some method for quickly checking for temporary threshold shifts should be established.
b). Semi-annual Audiograms Anyone exposed to impulse above 140 dB should be placed on a hearing conservation program, At a minimum, such a program should establish a baseline hearing threshold level for each exposed individual. After the baseline is established, at least two audiograms per year should be given to that individual. Changes in hearing threshold of 15 decibels or more at any frequency from .5 kHz to 6kHz should be the cause for intervention action.

c). TTS Checks While exposure to impulsive noise is occurring, it is recommended that a quick check for Temporary Threshold Shifts (TTS) in hearing be routinely accomplished.

6) Level at which non-auditory damage should be investigated.

a). General At sufficiently high sound pressure levels, injury to parts of the body other than the inner ear becomes a concern. The incidence and severity of such injury increases with sound pressure level, type of waveform and number of exposures. This standard does not provide the relationship of injury and the preceding parameters, but does provide in terms of Peak sound pressure level the evaluation threshold at which non-auditory injury may be of concern. . The standard will not cover the evaluation of exposures above this threshold. However, some possible approaches will be given for information only.

b). Evaluation threshold of non-auditory injury The evaluation threshold of non-auditory injury is set to be a level that is below the true threshold of injury for any reasonable type of impulsive waveform and for a reasonable number of exposures. This level is an unweighted (.01Hz to 10000 Hz) peak of 180 decibels or approximately 20 kPa.

c). Possible models for the evaluation of injury when the evaluation threshold is exceeded. There are established models and procedures for the evaluation of non-auditory injury. These will be given in an appendix of the standard and will be for information only. In addition, the formulation presented in my other paper at this meeting on a possible non-auditory design criteria will probably also be put into this appendix for information only. This formulation is:

For free field waves with a clearly defined A-duration under 10 ms

Max peak = 195 dB – 10 log (A-Duration) – 2.5 log (N)

And for all other transient waveforms

Max peak = 185 dB-2.5 log (N)

Where: The max peak is an average with a standard deviation of less than 1 dB

The A-duration is the time in milliseconds that the positive going peak overpressure stays positive without going negative.

For non-freefield waveforms, the Max peak is the greatest overpressure observed during the transient.

N is the number of individual transients during any day.

It is tempting, however, to try to make this part of the auditory standard. The 10 log t is an equal energy term, matching the survey method. The coefficient 2.5 of the "2.5 log N" term matches the range of 2 to 3 for this coefficient found for the best tradeoff using under-the-muff data (Patterson, et. al., 1997).

7) Peak level for fetal noise exposure The standard will also suggest that pregnant persons should not be exposed to peak levels above a c-weighted peak of 155 after the fifth month of pregnancy.

This recommendation is supported by the study of Gerhardt et al. (Gerhardt, et. al., 1998). Eleven pregnant sheep at a gestation of 127 days were exposed to twenty impulses using a shock tube 4 feet from the sheep. With the sheep removed, peak levels of an average of 169.7 dB were obtained at the position of the fetus. Slight elevations of evoked potential threshold were noted for low-frequency stimuli. Scanning electron microscopy revealed damage to hair cells in the middle and apical turns of the cochlea. Using a hydrophone within the uterus, the differences in attenuation between the air and the uterus varied 2 dB to 20 dB.

The 155 dBC value was derived by two approaches. The first approach assumed during the study that the average attenuation between the air measurements and the fetal head was 11 dB ((2+20)/2). The worst case situation of the fetal head next to the surface of the abdomen would indicate that such hair cell injury could have occurred from a peak 9 dB lower or 161 dBC. Because there is only one experimental point and injury occurred at this point, the threshold of injury is difficult to predict. However it seems reasonable to estimate this point by reducing the peak pressure by at least a factor of 2 (or 6 dB). This results in an estimate of a peak level of 155 dBC.

The second approach is to adjust the current peak limit of 140 dBC by a reasonable estimate of the amount of protection afforded by the abdomen and the lack of middle ear function. As shown in the previous approach, the womb may provide as little as 2 dB of attenuation. The lack of middle ear function results in an attenuation that ranges from 10 to 40 dB through 125 Hz to 2000 Hz (Gerhardt et al., 1992). This would indicate a limiting level from impulses in air could be anywhere from 150 (140+10) dBC to 180 (140+40) dBC. A 150 dBC limit would be a worse case estimate for both frequency and fetal position. Thus, a slightly higher value was considered to be reasonable. The 155 dBC peak limit was the value considered being a reasonable estimate.

The significance of the 155-dBC limit should not be underestimated. It basically means that a pregnant woman after the fifth month should not be using firearms greater than .22 cal.

D. Conclusions: The Standard of which I have outlined is currently a committee draft. It will be circulated for approval in the near future. Undoubtedly there will be some negative votes to resolve and some changes made. The fact that it does not contain the hazard risk curves of many existing procedures may worry some of the committee members. However, I believe that elimination of hazard risk curves that have been based on only one type of impulsive noise will lead to less hearing loss, while at the same time allowing the military to design larger and more energetic weapons. I personally believe that the manner that impulse noise has been handled up to now has been wrong. There is a complex relationship between the type of impulsive noise, the type of hearing protector, training of the users in the use of hearing protection and the motivation of the user of the hearing protection. These later two elements cannot be ignored and can not be predicted by a set of curves. They must be measured and continuously monitored, much as the performance of a weapon system is measured by "live-fire" exercises.

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